

MALAYSIAN PARASITES

XXXVII

AN INTRODUCTION TO THE ECOLOGY OF THE
MOSQUITOES OF THE LOWLAND DIPTEROCARP
FOREST OF SELANGOR, MALAYA

BY

W. W. MACDONALD AND ROBERT TRAUB

Reprinted from

STUDIES FROM THE INSTITUTE FOR MEDICAL RESEARCH
FEDERATION OF MALAYA

No. 29

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 1960		2. REPORT TYPE		3. DATES COVERED 00-00-1960 to 00-00-1960	
4. TITLE AND SUBTITLE Malaysian Parasites XXXVII: An Introduction to the Ecology of the Mosquitoes of the Lowland Dipterocarp Forest of Selangor, Malaya				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) United States Army Medical Research Unit (Malaya), Institute of Medical Research, Kuala Lumpur,				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 33	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

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PRINTED AT THE GOVERNMENT PRESS
BY B. T. FUDGE, GOVERNMENT PRINTER
FEDERATION OF MALAYA

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LOWLAND DIPTEROCARP FOREST OF SELANGOR, MALAYA*

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* These studies were supported jointly by the Federation Government, the U. S. Army Medical Research and Development Command, and by a grant from Colonial Development and Welfare Funds.

INTRODUCTION

Towards the end of 1955 the U.S. Army Medical Research Unit (USAMRU) began extensive collections of adult mosquitoes in Ulu Gombak Forest Reserve, Selangor. The mosquitoes were identified by one of us (W. W. M.) and the staff of the Division of Entomology of this Institute (I.M.R.), after which they were returned to USAMRU for attempted isolation of viruses. These catches were virtually the first regular forest collections in Malaya since Leicester's classical work at the beginning of the century (Leicester, 1908), and the problem which they immediately posed was one of taxonomy and nomenclature. Many of the species were unrepresented in the Institute collection, doubts often arose over the correct identification of specimens, and, consequently, much of the material could be identified only to a species group. The position was aggravated by the fact that virologists require large numbers of mosquitoes alive, or very recently killed, for their virus isolation work, and entomologists prefer mosquitoes on pins for definitive identification. In the event, most of the identifications were done while the mosquitoes were alive, but representative specimens were put aside for more leisurely examination.

It became clear from the adult catches of USAMRU that the mosquitoes of Ulu Gombak would repay closer study. Most species could not be separated satisfactorily with the existing keys, the larvae and males of many were unknown, and practically nothing was known of their breeding and biting habits. Following the recommendations of a conference on virus diseases held at the Institute for Medical Research in 1954 (Institute for Medical Research, Malaya, 1955), the investigation of those, and allied, problems has been a main concern of one of us (W. W. M.) for several years, and the following account is based principally on the collections of his unit. Since, however, the work of the I.M.R. and of the USAMRU teams has been in some ways complementary, and at times overlapping, it is convenient to present this introductory account jointly.

The work at Ulu Gombak has been supplemented by collections in other forest areas of Selangor, chiefly Ulu Langat Forest Reserve, Ampang Forest Reserve, Templer Park, and Bukit Lagong Forest Reserve, while a few collections have also been made in the forests of Negri Sembilan, Perak, Pahang, and Trengganu. Complementary investigations, which will not be discussed here, have gone on concurrently in coastal areas of Selangor, and in scrub terrain or "mosaic vegetation".

THE FOREST AND THE COLLECTING AREAS

The lowland forest of Malaya is evergreen tropical rain forest, dominated by trees of the family Dipterocarpaceae. Such forest is typical of Malaysia generally, where there is heavy rainfall, well-distributed over the year, and constant high temperatures and humidities, and dipterocarp forest is the climatic climax formation over much of this subregion. Discussions of the characters and features of Malaysian rain forest are given by Symington (1943), Wyatt-Smith (1952*a, b*) and Richards (1952). Following Symington (*l.c.*), five climatic climax forest formations are recognized in Malaya, each being characteristic of a different altitudinal zone. These are:

1. Lowland dipterocarp forest, which covers the plains and the foothills of the main range to an elevation of about 1,000 ft.
2. Hill dipterocarp forest, which covers much of the main range at elevations from 1,000 to 2,500 ft.
3. Upper dipterocarp forest, which extends between the altitudinal limits of 2,500 and 4,000 ft.
4. Montane oak forest, usually characteristic of elevations between 3,500 and 5,000 ft.
5. Montane ericaceous forest, which is found above 5,000 ft.

STUD. INST. MED. RES.

The altitudinal limits and the specific composition of each of those formations can not be rigidly defined, nor are they necessarily similar throughout the country. Under special climatic or topographical conditions the limits of each formation may be shortened or extended, and on coastal hills in particular the altitudinal limits may be telescoped.

Our collecting has been done principally in the first of the formations, i.e., lowland dipterocarp forest, but the mosquito fauna may not vary much between this and the higher dipterocarp formations. For example, almost all the mosquitoes recorded from The Gap*, which lies at about 3,200 ft. in the upper dipterocarp forest zone, have been collected also in Ulu Gombak Forest Reserve. On the other hand, there may be a gradual reduction in the number of species as one goes higher, and probably a number of lowland species do not extend into or beyond upper dipterocarp forest. Only more intensive and extensive collecting will provide the additional data that are required, but it is clear from our limited collections that there is a distinct change in the mosquito fauna when the montane oak or ericaceous forests are sampled, as at Fraser's Hill (4,280 ft.) and Cameron Highlands (5,000-6,000 ft.). The faunas of these high zones are poorer in species, and there are some species, e.g., *Toxorhynchites klossi*, *Tripteroides vicinus*, *Anopheles lindesayi* and *An. wellingtonianus*, which are not found at lower altitudes.

Unfortunately, lowland dipterocarp forest in Selangor has been extensively logged, so that there is little primary, undisturbed forest left. The areas with which we are concerned here, where mosquitoes have been investigated, are best described as secondary forest in which the tall dipterocarp trees have been thinned and secondary species have become established. In some respects this has proved an advantage, for among the secondary flora are bamboos, and the mosquitoes associated with these grasses are among our most interesting and abundant species.

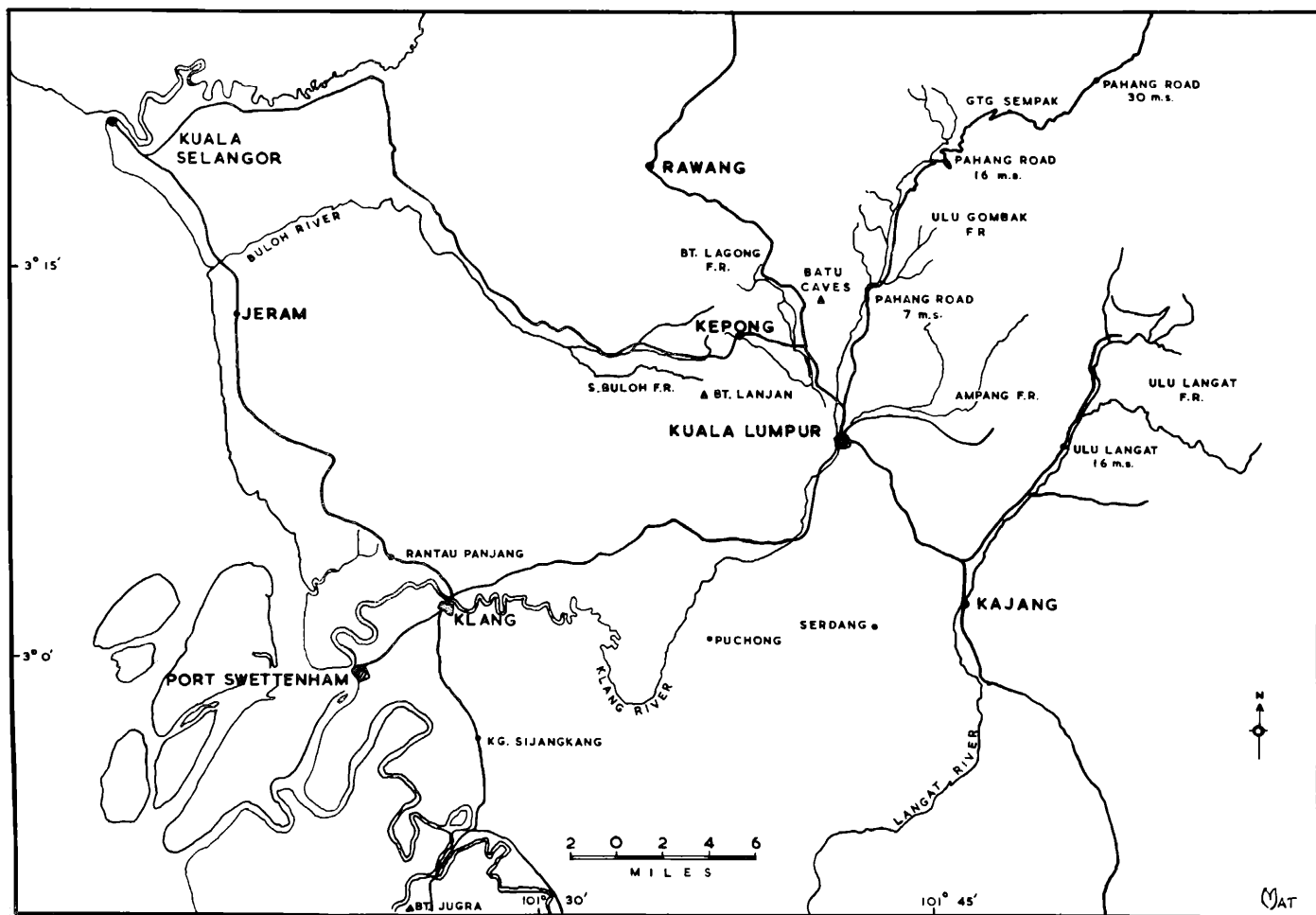
The collecting areas which will now be described briefly are as much as 15 or 20 miles apart, but the forest is continuous from one to another. The main differences between them lie in the degree of disturbance or interference by man, and this in turn is reflected in the secondary flora and in the mosquito fauna.

ULU GOMBAK FOREST RESERVE

This reserve has been the principal collecting area (*see* map). Through the forest-clad valley flows the River Gombak, which, rising near Genting Sempak, runs to Kuala Lumpur where it joins the River Klang. In the lower part of the valley, a few miles north of Kuala Lumpur, the forest has been cleared and the land given over to rice cultivation and rubber plantations. Forest is not now reached until about the 10th milestone, though when Leicester collected at Ulu Gombak in 1903-04 he was able to collect forest mosquitoes at the 5th milestone. Through the forested part of the valley wood-cutters' tracks are common, and logging is in progress in several areas.

Our collecting has been mostly between the 13th and 16th milestones, at an elevation of nearly 1,000 ft., where the land is hilly and the forest largely secondary. The crowns of the remaining giant dipterocarps, rising 100 ft. or more, are well-separated from one another and form a rather sparse emergent layer. There is no sharp discontinuity between the main storey (60-100 ft.) and the under-storey (25-60 ft.) so that these strata together form a more or less continuous canopy. The shrub and herb layers are quite dense, as would be expected in secondary forest, making travel difficult except along paths.

* Localities not shown on the accompanying map of Selangor were included in a map of Malaya in a previous account of mosquitoes in this series (Macdonald, 1957).



Map of Selangor, Malaya, showing the location of mosquito-collecting sites.

Bamboos of several species are a prominent feature of this reserve, especially near the roadside. The chief of these for our purposes are *Gigantochloa scortechinii* Gamble and *Dendrocalamus pendulus* Ridley, from both of which numerous collections of mosquito larvae have been made. Holttum (1958) has given a taxonomic account of Malayan bamboos, including those two species, but there is little information available on their ecology.

ULU LANGAT FOREST RESERVE

Situated due east of Kuala Lumpur (*see* map), this reserve is very similar in many respects to Ulu Gombak. The upper forested region has essentially the same flora, including bamboos, and the mosquito fauna shows every indication of being identical. Davidson and Ganapathipillai (1956) have given an account of the anophelines of the lower, populated portion of the valley, where they investigated the vectors of malaria.

AMPANG, KANCHING, BUKIT LAGONG, AND SUNGEI BULOH FOREST RESERVES

These reserves have been visited only occasionally. Each is much less disturbed than either Ulu Gombak or Ulu Langat and this is reflected both in the flora and in the mosquito fauna. Bamboos are less common, so that many species of mosquito which are associated primarily with bamboo are either absent or rare. North of Batu Caves and adjoining Kanching F. R. is Templer Park, a national park, which includes a large area of old tin-mining ground and some forest. This forest is disturbed, part of it has been treated silviculturally by the Forestry Department, and there are several small areas where bamboos are common.

COLLECTING AND REARING TECHNIQUES

The adult collections of USAMRU have already been briefly mentioned. Those were made using mosquito collectors as bait at various times during the day and evening, at stations near the 15 m. and 17 m. Ulu Gombak or Pahang Road. At the same time animal-baited traps were tried, but since these produced very few mosquitoes their use was discontinued. The human-bait catches were made principally on the ground, but, in addition, tree-top catches were made on a platform 90 ft. high on an old fig tree. Since the object of those early catches was to collect large numbers of mosquitoes for virus isolation attempts, the times of catching and the number of catchers were not standardized. Consequently, although a great deal of useful material was collected, no conclusions on biting times and seasonal abundance can be drawn from the results. At the same time the identification of the mosquitoes was not as precise as became possible later. With the exception of some results from the tree-top catches, these collections will therefore not be included in this account. Similarly, an analysis of the mosquitoes inoculated into mice for virus isolation attempts will not be given here, but it may be stated that no virus was recovered from Ulu Gombak (Institute for Medical Research, Malaya, 1957).

To fill the need for more precise data on the biting times and seasonal fluctuations of the various species at Ulu Gombak, sunrise-to-sunset catches were begun early in 1958, and these catches have continued on alternate weeks throughout 1958 and 1959. Occasional 24-hour catches of the pattern described by Haddow (1954) have also been made, but since the catch between sunset and sunrise has been consistently poor both in numbers and in species, most interest has been taken in, and emphasis placed upon, day catches. A few regulated catches have also been made on the tree-top platform mentioned previously.

In addition to the regular catches at Ulu Gombak, a few irregular adult catches have been made at Ulu Langat, Bukit Lagong, and Sungei Buloh Forest Reserves.

More than 500 larval collections have been made in the lowland dipterocarp forest of Selangor during the past three or four years, so that almost all the apparent breeding-places have now been well-sampled; but while larvae of the great majority of known species have now been collected, there still remain a number undetected. If the larvae could have been

readily identified much more could have been accomplished by larval surveys, but since a high proportion of the larvae encountered have never been described, or even collected before, a great deal of effort has gone into the rearing of each larval collection. With few exceptions, each larva of every collection has been individually reared to the adult stage, and the larval and pupal skins of many of them preserved and mounted, the correlation of the skins with the adults being the principal object of individual rearing. Since as many as 50-60 larvae may be collected from a single breeding-place, the number of collections has had to be curtailed. But the policy of rearing each larva individually is profitable in any area whose fauna is not well known, for even after collecting for three years, both new and unrecorded species have been found at Ulu Gombak.

There is one other technique which has contributed to our knowledge of forest mosquitoes. This has been the rearing of sibling series of specimens from individual females. Sometimes a species occurs more or less regularly in adult catches, whereas attempts to find the breeding-places fail. In such cases we have endeavoured to feed a wild-caught female and induce her to lay her eggs in the laboratory. From such an egg-batch an excellent series of larvae, pupae, and adults can usually be obtained, and in those groups where males are necessary for positive identification this may be the only way of determining the true status of the female parent. Many species will lay their eggs on damp filter paper in a tube such as was described by Macdonald (1956) for *Ae. aegypti* egg-laying. This applies more particularly to species of *Aedes*, *Heizmannia*, and *Armigeres* subgenus *Armigeres*, which lay their eggs individually. Species of *Culex* and *Armigeres* subgenus *Leicesteria*, which lay their eggs as a raft or a ribbon, are best kept in a small jar with water.

Since many species do not readily feed in captivity, for example most species of *Heizmannia*, the mosquito collectors in the field have often allowed each mosquito to feed to repletion, in the hope that the catch would include one or more species required for egg-laying. In this manner the first, and only, known series of *Heizmannia achaetae* adults with associated skins was obtained. It may be of interest to add that even when a female is collected unfed, and subsequently refuses to feed in the laboratory, it is worthwhile retaining her in a tube with damp filter paper in case there are a few eggs left over from the previous oviposition. By this method seven eggs of the rare species *Udaya lucaris* were obtained, and from the eggs the only known larvae, pupae and males were reared (Macdonald and Mattingly, 1960).

Besides providing valuable series of specimens, the technique of inducing wild-caught females to lay eggs in the laboratory also allows observations to be made on the different methods of egg-laying, and on the effect of subjecting the eggs to slow drying such as they might meet in nature.

THE BREEDING-PLACES

Before discussing the mosquito fauna itself it is necessary to tabulate and summarize briefly the breeding-places that have been sampled. Those are shown in Table I, which also includes the number of species that has been collected from each habitat. A number of the table headings can be subdivided further, and additional data are in fact given in later tables and in the text.

TABLE I

THE TYPES AND NUMBERS OF BREEDING-PLACES SAMPLED, TOGETHER WITH THE NUMBER OF SPECIES COLLECTED FROM EACH, IN LOWLAND DIPTEROCARP FOREST, SELANGOR

Breeding-place	Tree-holes	Artificial containers	Bamboo stumps	Fallen and Upright Split bamboo	Upright bamboo internodes with holes	Plant Containers	Rock-pools	Temporary Pools	Permanent pools and swamps	Totals
No. of collections	100	72	58	54	164	33	16	6	29	532
No. of species	46	20	35	40	41	15	10	9	27	127

STUD. INST. MED. RES.

Tree-holes.—These require little explanation. The holes may range in size from small cavities holding only 100 mls., or less, to large, deep holes containing several litres of water. All those examined have been situated near ground level, so that tree-holes in the canopy have not been investigated. No effort was made to group the holes by size, or by any other criterion, but in view of the large number of species that has been recorded from this habitat (46 species of 11 genera), it now seems likely that a careful study of individual holes and cavities might reveal characteristics common to some but not to others that might be related to the presence or absence of the various mosquito species.

Artificial containers.—These include bamboo pots and plastic jars, chiefly the former, that have been placed in various situations and examined at intervals. Most of the containers have been near ground level, but there were also three series of bamboo pots placed at heights between ground level and 94 ft.; those were examined weekly and the larvae, when present, were sampled. Almost all the species collected from artificial containers have been found also in tree-holes.

Bamboo stumps.—This habitat is a common source of a good variety of species. In almost all cases the stumps were between ground level and a height of 6 ft., but occasionally a collection has been made from a taller bamboo whose upper portion had broken off. As in the case of tree-holes, the volume of water in bamboo stumps varied a lot, depending mainly, of course, on the depth of the internode as well as on weather conditions.

Fallen and upright split bamboos.—This group includes fallen bamboos principally, but in all cases the bamboos have been split along the long axis and water has collected in one or other of the internodes. In most cases the cracks have been of sufficient size to allow easy ingress by the mosquitoes, but occasionally in upright bamboos the vertical split was so narrow that many species would be unable to pass through.

Upright bamboos with holes.—Holes in the wall leading inside the internodes are not uncommon in upright bamboos, and they have been divided by size into three groups: small holes, less than 5 mm. along the greatest axis; moderate-sized holes, 5-10 mm.; and large holes more than 1 cm. along the longest axis. The small and moderate-sized holes have, as a rule, been bored by beetle larvae, but a full account of the formation of the different types has been given elsewhere (Macdonald, 1960b, this *Study*). An interesting and complex mosquito fauna is found inside the internodes, and not only is the size of the entrance hole of significance, but so also is the age and condition of the bamboo.

Plant containers.—These records include collections from the leaf axils of plants such as bananas (*Musa*) and keladi (*Colocasia* and/or *Alocasia*), collections from the inflorescence of the wild ginger plant *Zingiber spectabile*, from fallen leaves, and a few from pitcher plants. Some mosquito species seem to be very closely associated with only one species of plant, so that one might describe them as plant-specific.

Rock-pools.—These have usually been situated beside one or other of the Selangor rivers, but a few collections were also made from small pools of rain-water on boulders at the forest edge.

Temporary pools.—These include all small bodies of water which are dependent mainly on rain-water for their existence. Included are small pools of seepage water and the occasional collections of water in hoof prints; but, in general, this is not a common nor important group of breeding-places in forest.

Permanent pools and swamps.—Permanent bodies of ground water are not common in lowland dipterocarp forest, but the records include a number of collections from an old, disused

aqueduct at Ulu Gombak. This aqueduct measures about 5 ft. across and contains standing water to a depth of several inches during most of the year; it also contains a large amount of fallen vegetable debris such as leaves and branches. It is therefore best classified as a permanent pool, and it provides a breeding-place for a number of species which are probably secondary, introduced species in the forest.

It has become increasingly evident during the course of collecting that very detailed recording of the breeding-places is necessary before the individual preferences of the various species can be defined. Some species of most genera can be associated with a simple observable niche, but there are others whose preferences and habits are obscure. The most unsatisfactory group are those species which breed in tree-holes and bamboo-stumps. It is certain, for instance, that the 46 species recorded from tree-holes do not have identical breeding requirements, including as they do many species of the same genera and subgenera, but at present there are insufficient data to subdivide these breeding-places further. Progress will be made when the regular study of a limited number of tree-holes is possible, but ultimately it may prove necessary to define the several niches within each single breeding-place, and to clarify the complex inter-and intra-specific relationships.

THE MOSQUITOES OF THE FOREST

The following arrangement follows that of an earlier review of Malayan mosquitoes (Macdonald, 1957), which included notes on species distribution and in which the authors of each species were given in full: only species not mentioned in that review will be given in full here. At the same time many references to taxonomic accounts of the various groups are omitted since those were also given earlier. In this account emphasis is placed on the ecology of the forest species, and wherever there are sufficient data an attempt is made to define the niche occupied by each.

Despite the great variety of species in dipterocarp forest, and especially at the forest fringe, it is exceptional for mosquitoes to be a serious nuisance either by day or by night, and many of the species listed in the following pages have never been taken attacking man. This situation contrasts with that in swamp forest, where one finds fewer species but usually much larger numbers of individuals, chiefly of the genus *Mansonia*. Similarly, in the *Nipa* and coconut plantations along the coast the same situation obtains; only about half as many species as occur in inland forest are known, but several of them, chiefly species of *Aedes*, occur in very large numbers at times, and they attack man vigorously.

It is well perhaps to emphasize that the rich variety of species in forest may be characteristic only of secondary or disturbed forest, particularly where bamboos are established. No extensive observations have yet been made in primary forest, but there are indications that the mosquito fauna may be poor both in numbers and in species. It is certainly wrong to think of primary dipterocarp forest as harbouring large numbers of voracious mosquitoes, or other biting insects. Generally speaking, mosquitoes are more abundant in the botanically more simple formations, where one or two types of mosquito breeding-place usually outnumber all others, and so produce large numbers of only a few mosquito species. Such conditions are fulfilled in swamp forest and in the *Nipa* palm-mangrove zone.

Except in the case of the genus *Anopheles*, work on the systematics and taxonomy of Malayan mosquitoes is still far from complete, and in the following notes it has been necessary to refer to some species by numbers. In most of these cases a few descriptive notes have been added, and those might be helpful in recognizing the species until full names and descriptions can be provided. The number given to a species is only a temporary measure, but to avoid future confusion, representative specimens of each species will be deposited in the British

Museum (Natural History), and, as the systematics of the various groups are clarified, it is hoped that the numbered specimens will serve as a link between the future taxonomic descriptions and the ecological notes given in this paper.

Genus *Toxorhynchites* Theobald

Only four species of this non-biting genus have been collected by us in lowland forest—*leicesteri*, *magnificus*, *metallicus* and *quasiferus*; their breeding habits are shown in Table II. In addition, two other species, *funestus* and *raris*, were each collected once by Leicester (1908) from bamboos in forest near Kuala Lumpur; and there is also a single female of *funestus* in the I.M.R. collection recorded from 11 $\frac{3}{4}$ m. Pahang Road (*E. P. Hodgkin*), i.e. from Ulu Gombak. A total of six species are therefore known to occur in lowland dipterocarp forest.

TABLE II

THE COLLECTIONS OF *Toxorhynchites* RECORDED FROM
VARIOUS BREEDING-PLACES IN LOWLAND DIPTEROCARP FOREST, SELANGOR

Species	Total collections	Tree-holes	Bamboo pots	Bamboo stumps	Bamboos, fallen, split	Bamboos, with large holes	Bamboos, with moderate holes	Bamboos, with small holes	Ginger flower bracts	<i>Orchidantha</i> axil
<i>funestus</i> ...	—				?					
<i>leicesteri</i> ...	2				2					
<i>magnificus</i> ...	18			1		2	9	6		
<i>metallicus</i> ...	24	1	5	10	2	3	3			
<i>quasiferus</i> ...	17	12	1			1	1		1	1
<i>raris</i> ...	—				?					

Of these, *magnificus*, *metallicus* and *quasiferus* are most common, and each occupies a distinctive larval niche. The first, *magnificus*, breeds almost entirely in upright bamboo internodes, the entrance to each internode being a small or moderate-sized (occasionally large-sized) hole in the bamboo wall. In view of the large size of the adult mosquitoes the method by which the female enters the internode to lay her eggs is rather a mystery. The second species, *metallicus*, breeds mainly in bamboo stumps, but larvae may be found occasionally in split bamboo, tree-holes, or in internodes with moderately large holes in the wall. The third species, *quasiferus*, clearly prefers tree-holes although a few collections have been made from other habitats; two collections from plant axils suggest an unusual degree of plasticity in the behaviour of the female when she is selecting a site for egg-laying.

The remaining three forest species have this in common—each was collected from bamboos; but the larval habitat which seems least exploited by any species is “fallen, split bamboo” and this is very surprising in view of the large numbers of other mosquito larvae which are usually present, and which would serve as food for the carnivorous *Toxorhynchites* larvae.

It is very noticeable that in collections containing *Toxorhynchites* there is usually, though not always, only one *Toxorhynchites* larva. In the species which have been investigated (see Horsfall, 1955) eggs are laid singly on the water surface, but there seems to be no evidence that only one egg is ever laid, though this may at times be the case. The explanation of the single larva in collections is probably that this larva represents the sole survivor of the original batch and that during their very long larval life *Toxorhynchites* prey and feed on one another just as readily as they do on the larvae of other genera.

Of the remaining four Malayan species of *Toxorhynchites*, three are pitcher plant breeders; and whilst pitcher plants are not typical of lowland dipterocarp forest, *Nepenthes ampullaria*

may occasionally be found under some circumstances. In such cases, *T. acaudatus* is likely to be present. The fourth species, *T. splendens*, is found in coastal areas (*see* also Macdonald, 1957).

Genus *Tripteroides* Giles

Five species of *Tripteroides* have been previously recorded from lowland dipterocarp forest, but practically nothing has been known about their habits. Two or three others have now been collected, but unfortunately the systematics of these have not yet been clarified. Accordingly, three species are at present known by numbers. Table III summarizes the data on the breeding habits of each species, but before elaborating on these, it is worth recording how discrepancies in ecological data can suggest errors in taxonomy. In Table III 32 collections of "*coeruleocephalus*" are recorded: adult mosquitoes from all of those collections had been routinely examined and identified as *coeruleocephalus*. When the breeding-places were listed and analyzed, however, it was realized that the collections fell into two groups—those from bamboo internodes with small or moderate-sized holes in the bamboo wall, and those from tree-holes or from artificial containers. In other words there was a clear suggestion that two species were being confused; and such proved to be the case. Specimens from most of the early collections are no longer available, but it appears from subsequent collections that only the bamboo-breeders were *coeruleocephalus*, while those from tree-holes were species no. 2, an unidentified species belonging perhaps to the *powelli*-group. A third species, species no. 1, may also have occurred in some of the early collections, since the females cannot at present be easily distinguished from females of species no. 2.

Rather similar doubts have arisen over the identity of *aranoides*. As Table III shows, larvae of this non-ornate species have been collected from a wide range of habitats in lowland forest; but the majority of collections have come from bamboo internodes, and it is therefore probable that only one forest species is present. However, since an apparently similar species may be collected from, among others, such habitats as highland pitcher plants, lowland pitcher plants, and artificial containers inside houses, it is clear that there are grounds for re-examining the status of *aranoides*. The species was described from a single Malayan female from Taiping, Perak, by Theobald (1901: 274) but there is no information available which might help decide the habitat of the larvae. It is interesting to note that Baisas and Ubaldo-Pagayon (1952), in revising the *Tripteroides* of the Philippines, record all 10 of their non-ornate species as nepenthicolous, while all but 3 of the 20 species and sub-species of ornate *Tripteroides* were non-nepenthicolous in habitat.

TABLE III

THE COLLECTIONS OF *Tripteroides* RECORDED FROM VARIOUS BREEDING-PLACES IN LOWLAND DIPTEROCARP FOREST, SELANGOR

Species	Total collections	Tree-holes	Artificial containers	Bamboo pots	Bamboo stumps	Bamboos, fallen, split	Bamboos, upright, cracked	Bamboos, with large holes	Bamboos, with moderate holes	Bamboos with small holes	Ginger Rock-flower pools bracts
<i>aranoides</i> ...	56		1	11	6	5	3		16	13	1
" <i>coeruleocephalus</i> "	32	6	3						21	2	
<i>coeruleocephalus</i> ...	7					1		2	2	2	
<i>similis</i> ...	4					4					
species no. 1 ...	2	1				1					
species no. 2 ...	16	10	2	3							1
species no. 3 ...	1	1									
<i>aeneus</i> ...	not yet collected										
<i>proximus</i> ...	possibly species no. 2										

T. aranoides is a very common species in larval collections from Ulu Gombak, but the adult has never been taken in biting catches. This is the only non-ornate species which has been found in forest; all the other species fall into the ornate group with blue head scales, spotted femora, etc.

T. coeruleocephalus is also common in the bamboos of lowland forest. As already mentioned, the adult mosquito is rather similar to several other species, but the larva and pupa are very distinct. Leicester (1908), in describing this species, did not mention the early stages, but Daniels (1908: 266), contrasting *mendacis* and *coeruleocephalus*, drew attention to the long, relatively narrow, larval siphon and to the long, very thin, pupal trumpet. Like *aranoides*, *coeruleocephalus* demonstrates a preference for bamboo internodes, entering the internode through small or moderate-sized holes in the bamboo wall.

T. similis has been collected only occasionally, and each of four collections was made from fallen, split bamboo.

Species no. 1 is probably a new, undescribed species. The adult male is most distinctive on account of highly modified fore and mid tarsi, and modified fore claws; these features are quite unique, so far as is known, in the genus. Since only two collections have been made in lowland forest, from a tree-hole and a fallen bamboo, the breeding preferences are uncertain. Two other collections were, however, made outside Selangor: the first from a tree-hole on Gunong Tebu, Trengganu (*W. W. Macdonald*); the second from a discarded tin can in the forest fringe at Fraser's Hill (*J. A. Reid*).

Species no. 2 is quite common at Ulu Gombak, breeding principally in tree-holes. The early stages and the male distinguish it from *coeruleocephalus* and species no. 1 respectively. In the male, unequal mid claws and the simple, larger fore claw serve to separate it from the following species.

Species no. 3 is not common, but in addition to the single collection shown in Table III (from Templer Park), several collections have been made outside Selangor. In the male, the prominent tooth of the larger fore claw, together with equal mid claws, are distinctive.

It may be that species no. 2 is the same as *T. proximus* recorded by Edwards (1915) from Ulu Klang (Selangor) and from Ulu Gombak, but Edwards' description is inadequate for a decision on this point.

Edwards (1921) has described another species, *T. aeneus*, which came from "edge of stream, Ampang jungle," but we have not seen any specimen which could be ascribed to this species. Nevertheless, *aeneus* must be regarded as a lowland forest species.

In this brief account we have not mentioned nepenthicolous species, principally because pitcher plants are not typical of lowland dipterocarp forest except in some areas where there are special soil conditions. Pitcher plant collections from forest outside Selangor have produced a species we have been calling *aranoides* and at least one other species which is related to *T. nepenthis*, and which may be new.

The genus *Tripteroides* is therefore well-represented in lowland dipterocarp forest and the larvae are common, but only rarely is a specimen taken in biting catches. A female *coeruleocephalus* which was reported attacking man in the canopy of a patch of Kuala Lumpur forest (*Macdonald*, 1957) is almost certainly a misidentification. Unfortunately females can not yet be identified reliably, but taking into consideration the availability of breeding-places in this patch of forest it seems likely that the specimen was a tree-hole breeder, perhaps species no. 2.

Genus *Topomyia* Leicester

The genus *Topomyia* is primarily a group of forest mosquitoes, and no species is known to take blood. Identification of the females is difficult in a number of cases, particularly when the mesonotal stripe is rubbed, but the male terminalia, figured by Edwards (1922), are very characteristic for each species. Probably most species breed in plant axils, but two, *decorabilis* and *spathulirostris*, are found in bamboo internodes, and another, *tenuis*, has been collected occasionally from tree-holes. Table IV shows the species recorded from lowland dipterocarp forest together with the breeding-places that are known.

There are several reasons for thinking that *aureoventer* is a synonym of *tipuliformis*: thus, only females of *aureoventer* and only males of *tipuliformis* have ever been collected; secondly, both have been reared from the same plant axils on several occasions; and lastly, no differences can be seen between the larval and pupal skins of the respective male and female adults. On the other hand, Edwards (1922: 441) mentions a female in the British Museum (Nat. Hist.), collected but not described by Leicester, which he thought might be the female of *tipuliformis*. Since pronounced differences are usually present between the larvae of different species of *Topomyia*, or at any rate between those larvae which are known, the similarities between the larvae and pupae of *aureoventer* and *tipuliformis* are themselves almost sufficient to conclude that Leicester (1908) described the same species twice.

TABLE IV

THE COLLECTIONS OF *Topomyia* RECORDED FROM VARIOUS BREEDING-PLACES IN LOWLAND
DIPTEROCARP FOREST, SELANGOR

Species	Total collections	Tree-holes	Bamboos, upright, cracked	Bamboos, dead, with moderate holes	Bamboos, alive, with moderate holes	Bamboos, dead, with small holes	Bamboos, alive, with small holes	keladi axils (Araceae)	Banana axils	<i>Orchidantha</i> axils (Lowiaceae)	Ginger flower bracts	<i>Pandanus</i> axils (screw- pine)
<i>aureoventer</i> (? = <i>tipuliformis</i>)	2							1	1			
<i>decorabilis</i> ...	4			4								
<i>dubitans</i> ...	1							1				
<i>gracilis</i> ...	1							1				
<i>spathulirostris</i> ...	36		1	5	10	14	6					
<i>tenuis</i> ...	7	2									5	
<i>tipuliformis</i> ...	4							3		1		
species no. 1	1											1
<i>argyropalpis</i> ...	adults only											
<i>nigra</i> ...	adults only											
<i>minor</i> ...	not yet collected											
<i>argenteoventralis</i> ...	not yet collected											
<i>rubithoracis</i> ...	not yet collected											

T. dubitans, *gracilis* and *tipuliformis* are all found in plant axils such as *Colocasia*, *Alocasia*, (jointly grouped as "keladi"), wild bananas, etc., and one collection of *tipuliformis* was from the axil of *Orchidantha longiflora* (Lowiaceae), a ground herb comparable to the better known *Colocasia*. Additional collections of all three species are required before breeding preferences and specific differences in those preferences will become apparent.

T. decorabilis has been found only in the internodes of dead bamboos, the highest collection being situated at a height of 23 ft. In each case the entrance into the internode was a moderate-sized beetle hole. As Edwards (1922) pointed out, the adults have several unusual features, and it is interesting to find that the larvae also are unusual. Like the related species *T. imitatus* of the Philippines (Baisas, 1946), which has very similar male terminalia, the larva of *decorabilis*

has enlarged maxillae with "articulated horns", very like the maxillae of *Goeldia* and *Tripteroides* sub-genus *Rachisoura*. The relationship between *imitatus* and *decorabilis* is perhaps strengthened by the fact that the single larva of *imitatus* which was collected came from the "cut joint" of a bamboo.

T. spathulirostris has been collected more often than any other species, and it also breeds in bamboo internodes. However, there does not seem to be any particular preference for living as opposed to dead bamboos, and the entrances into the internodes vary from very small to moderate-sized beetle holes.

T. tenuis is the only other species whose preferences are more or less well-defined. This is the species which is commonly found breeding in the bracts of the inflorescence of *Zingiber spectabile* (Zingiberaceae), a striking ginger found from Negri Sembilan northwards (Henderson, 1954).

An unnamed species, species no. 1, has been collected once from the axils of *Pandanus* (screw-pine); it may be that this species is one of those mentioned in the following paragraph.

Of the remaining species, *argyropalpis* and *nigra* have each been collected only as adults at Ulu Gombak, by sweep-netting, and the early stages are unknown. *T. minor* has been recorded by Leicester (1908) from forest near Kuala Lumpur, but the two other Malayan species, *argenteoventralis* and *rubithoracis* are known only from The Gap, i.e., in upper dipterocarp forest, though it seems very likely that both might occur in lowland forest also.

Genus **Malaya** Leicester (= **Harpagomyia** de Meijere)

Stone and Knight (1957) have revalidated the name *Malaya*, and the more familiar name *Harpagomyia* has therefore been relegated as a synonym.

Larvae of this genus which were collected at Ulu Gombak from axils of 'keladi' (*Colocasia* and *Alocasia*: Araceae) were unfortunately not retained, but it is most likely that they were *M. jacobsoni* (Edwards), a species not previously recorded from Malaya but adults of which have been taken at Ulu Gombak. As is well known the mosquitoes of this genus obtain food from ants of the genus *Cremastogaster* (see also Horsfall, 1955: 335), and one of us has made the following observations on the feeding habits of *M. jacobsoni*.

At Ulu Gombak the mosquitoes are very common when the annual crop of young bamboos appears towards the end of the year. At those times *Cremastogaster* ants may be seen feeding on the juices of the succulent growing tip of each young bamboo, and, having fed, they then return downwards with their abdomens distended. Hovering a short distance from the bamboo culm, or flying up and down in a vertical plane, may be seen the female *M. jacobsoni*. As many as 6-10 mosquitoes may congregate around one bamboo, and, at irregular intervals, each mosquito alights in front of a downwardly-travelling ant, inserts its proboscis into the mouth of the ant, and acquires a droplet of fluid. The ant and the mosquito remain in contact for as long as 20-30 seconds though more often for shorter periods, then the mosquito continues its flight parallel to the bamboo until another ant is selected and the operation is repeated.

It seems likely that there may be an annual rise and fall in the numbers of *M. jacobsoni*, the rise being related to the appearance of young bamboos, since adults and larvae appear to be rare at times of the year when young bamboos are absent.

Genus **Hodgesia** Theobald

Both Malayan species of this widespread genus, *malayi* and *quasisanguinea*, have been collected in lowland forest, but the breeding-places of only *malayi* have been found; larval collections were made mostly from the standing, shallow water of the disused aqueduct at

Ulu Gombak, but also from seepage and ground pools. Occasional adults of both species have been taken in biting catches during the day and early evening, but neither species is common. Of the two, *quasisanguinea* has been collected rather more often in adult catches.

Genus *Zeugomyia* Leicester

Z. gracilis, the only Malayan species of this genus, is found principally in fallen leaves on the forest floor. *Aedes jugraensis* and *Uranotaenia obscura* are often associated with *gracilis*. Only rarely has the adult been taken in biting catches, although Leicester (1908: 233) describes it as a vicious biter. Since fallen leaves with water are only found after rain, one may deduce that *gracilis* has some means of surviving through dry spells. Probably the eggs can withstand drying, but this should be confirmed. The larvae are certainly able to survive for some time on a leaf from which most of the water has evaporated, and one may find larvae on leaves which are wet or damp. Edwards and Given (1928) describe the larvae, which are reputed to be predacious on those of *Ae. jugraensis* and *Ur. obscura*. The same authors mention the ability of *gracilis* larvae to attach themselves to a leaf by their mouthparts when the water in the leaf is poured off; this adaptation is not limited to *gracilis* as Edwards and Given suggest (*see also Ur. obscura*).

Genus *Uranotaenia* Lynch Arribalzaga

A number of species of *Uranotaenia* are well-represented in forest larval collections, but adults are very rare in biting catches. Once again the breeding-places can best be summarized in tabular form, Table V. Most species have been collected only occasionally, but three—*lutescens*, *modesta* and *obscura*—are quite common.

A single collection of *bimaculata* was made at Ulu Gombak from an internode of an old, dead, fallen bamboo, the entrance into the internode being one or other of two small beetle holes. Only a single specimen of *bimaculata* was reared from this collection, but in the I.M.R. collections there are three other old specimens one of which is labelled "bamboo." Another specimen has been taken at Ulu Gombak by sweep-netting.

TABLE V

THE COLLECTIONS OF *Uranotaenia* RECORDED FROM VARIOUS BREEDING-PLACES IN LOWLAND
DIPTEROCARP FOREST, SELANGOR

Species	Total collections	Tree- holes	Artificial containers	Bamboo stumps	Bamboos, fallen, split	Bamboos, with mode- rate holes	Bamboos, with small holes	Fallen leaves	Aqueduct	Ground pool
<i>bimaculata</i> ...	1						1			
<i>bimaculiala</i> ...	1								1	
<i>cf bicolor...</i> ...	1	1								
<i>campestris</i> ...	1								1	
<i>cf longirostris</i> ...	2								1	1
<i>lutescens</i> ...	22	1	2	2	12	5				
<i>modesta</i> ...	35	15		12	4	4				
<i>obscura</i> ...	11							11		
<i>cf recondita</i> ...	2			1	1					
<i>testacea</i> ...	1								1	
<i>trilineata...</i> ...	adults only									
species no. 4 ...	adults only									
species no. 7 ...	adults only									
<i>argyrotarsis</i> ...	not yet collected									
<i>unimaculiala</i> ...	not yet collected									

Ur. bimaculiala, *campestris*, *cf longirostris* and *testacea* have each been collected from still, standing water. Only a few collections have been made, and while these reflect to some extent the limited collecting from standing water in forest, it is probably true to say that none of the four species is a common forest mosquito. *Ur. testacea* has also been collected on several

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occasions by sweep-netting; and both *bimaculiala* and *campestris* have been collected from ground pools in the open, non-forested, lower Ulu Gombak valley. The identity of the species recorded as cf *longirostris* is in doubt. There is another species, from coastal areas, which is similar in some respects but is probably specifically distinct. Leicester (1908: 217) did not mention the locality where he collected the type, but it is quite possible that the coastal species is *longirostris* s. str. and that those specimens from Ulu Gombak forest belong to an undescribed species.

Ur. cf bicolor has been found only once at Ulu Gombak (in a tree-hole), but collections of apparently the same species were made from tree-holes near the base of Gunung Tebu, Trengganu. The identity of the specimens is in doubt since *bicolor* s. str. is probably a pool-breeder in open country. The type came from "the marshy edges of a jungle stream in Kuala Lumpur" (Leicester, 1908: 225), and collections have been made of Leicester's species in seepage pools, and in a small temporary pool in a hoof-print, around Kuala Lumpur. It seems unlikely that the same species is also a tree-hole breeder in forest, but the material in the I.M.R. collection has not yet been critically examined.

The habits of *lutescens* can be better defined. Larvae are found principally in fallen, split bamboos, but they may also occur in bamboo internodes with moderate-sized holes, or in bamboo stumps and (rarely) tree-holes.

Ur. modesta, on the other hand, shows a clear preference for tree-holes and bamboo stumps, with only occasional collections being made from fallen or upright bamboo internodes. The preferences of *lutescens* and *modesta* extend therefore over the same range of breeding-places, but, as Table V shows, the species are distinctly different in their primary selections.

Ur. obscura, like *Z. gracilis*, is confined to wet, fallen leaves on the forest floor, and when the water of a leaf is poured off, the *obscura* larvae may be seen anchoring themselves by their mouthparts to resist the flow of water. The larvae are in fact quite difficult to dislodge.

Larvae of one other species, *Ur. cf recondita* Edwards, have been collected; once from a bamboo stump and once from a fallen, split bamboo. As in the case of several other species, confirmation of the identification is required, particularly since *recondita* has not previously been recorded from Malaya.

Adults of three of the remaining species, *trilineata*, species no. 4, and species no. 7, have been collected by sweep-netting at Ulu Gombak, but the larval habits are unknown; Leicester (1908: 206), however, records *trilineata* from pools beside jungle streams. Two other species, *argyrotarsis* and *unimaculiala* have been recorded from forest by Leicester but have not yet been collected by us; *argyrotarsis* is reported to be a jungle pool breeder (Leicester, 1908: 215).

A few distinguishing features of species no. 4 and species no. 7 may be mentioned briefly.

Species no. 4.—Rather like *bimaculata*, but in addition to the pair of prominent, dark-brown spots in front of the wings, there is another pair anteriorly, above the posterior pronotum. There is also a dark-brown spot in front of the mid-lobe of the scutellum. Ground colour of mesonotum light brown, pleurae pale, legs dark-brown, abdominal tergites dark-brown.

Species no. 7.—The single male resembles *testacea* closely, but segments IV and V of the hind tarsi are not white. The specimen also lacks the slender hairs which are present on the mid-femur of *testacea* males. Mesonotum and pleurae as in *testacea*. Abdomen rubbed, but apparently unicolorous.

Genus *Orthopodomyia* Theobald

This genus has been reviewed recently (Macdonald, 1958), and the breeding habits of the five Malayan species summarized. All the available data are now presented in Table VI.

TABLE VI

THE COLLECTIONS OF *Orthopodomyia* RECORDED FROM VARIOUS BREEDING-PLACES IN LOWLAND
DIPTEROCARP FOREST, SELANGOR

Species	Total collections	Tree- holes	Bamboo pots	Bamboo stumps	Bamboos, fallen, split	Bamboos, upright, cracked	Bamboos, with large holes	Bamboos, with mode- rate holes	Bamboos, with small holes	<i>Polystictus xanthopus</i>
<i>albipes</i>	54	1	1	5	8	5	1	29	4	
<i>andamanensis</i> ...	7	6		1						
<i>anopheloides</i> ...	2	2								
<i>maculipes</i>	9	9								
<i>wilsoni</i>	5				1	1		2		1

O. albipes is the most common species, having been collected more than 50 times; but although the larvae are common, adults are rare in biting catches. Larvae may be found in a wide range of bamboo breeding-sites, but the preferred habitat appears to be internodes which can be entered through moderate-sized holes. The collections were about equally divided between living and dead bamboos; and although most of the collections were from near ground level, others came from internodes at heights ranging from 3 to 22 ft.

O. andamanensis, *anopheloides* and *maculipes* have been collected almost entirely from tree-holes, and although two of the species may at times be found together, it is not unlikely that a more careful study of the tree-holes would reveal differences which could be detected by the mosquitoes, and which could be correlated with the presence or absence of each species.

The breeding preferences of *O. wilsoni* Macdonald seem to overlap those of *albipes*, and at present no clear distinctions can be drawn between them. As concluded elsewhere (Macdonald, 1958) *wilsoni* and *albipes* are more closely related to each other than to the remaining three species; nevertheless, there must be a significant difference in their ecology which results in one species, *albipes*, being ten or eleven times more common than the other. *Polystictus xanthopus* Fr. (Polyporaceae), shown in Table VI as a breeding-place of *wilsoni*, is a small fungus. A photograph was published by Chu (1958), who recorded *Aedes (F.) greeni kanaranus* (= *aureostriatus kanaranus*) breeding in it.

Genus **Ficalbia** Theobald

This genus has been treated systematically by Mattingly (1957a). Most species breed in ground-pools, but those of subgenus *Ravenalites* have been recorded from tree-holes, bamboo stumps, etc. The only common forest species in Malaya, *fusca*, belongs to that subgenus. *F. fusca* has been collected from tree-holes (6 times) and rarely from bamboo internodes with small or moderate-sized holes (one collection from each habitat), but it is not confined to lowland forest. Collections have been made at Fraser's Hill and Cameron Highlands, and also from a tree-hole near the mangrove zone on the Selangor coast.

F. luzonensis has been taken at the 11 m. Ulu Gombak road from a swampy area near the roadside, which is best classified as forest fringe. This species is, however, more typical of ground pools in open, non-forested localities.

Genus **Mansonia** Blanchard

The mosquitoes of this genus are most typical of swamp forest, where they breed in enormous numbers. Elsewhere larvae may be found in ground pools sometimes associated with particular aquatic plants, to the roots of which the larvae attach. In lowland dipterocarp forest occasional adults of *annulata*, *bonneae*, *dives*, *indiana* and *uniformis* have been taken in biting catches, but adults are uncommon except where there are nearby swampy pools suitable

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for breeding. Larvae of *bonneae* have been collected from swampy pools at the forest edge at Sungei Buloh, where adults were also common, but since *Mansonia* mosquitoes are generally rare in dipterocarp forest, little attention has been given to searching for breeding-places, which is a laborious business owing to the special habits of the larvae.

In swamp forest this group is very important, particularly because several species are vectors of filariasis. Wharton (1957) has published observations on the rearing and maintenance of a colony of *uniformis*, and, in the course of work on filariasis, has also recorded data on the *Mansonia* breeding-places in swamp forest, their feeding preferences, etc. (Institute for Medical Research, Malaya, 1958).

Genus **Aedomyia** Theobald

The single Malayan species, *catacticta*, is not known to occur in lowland dipterocarp forest.

Genus **Aedes** Meigen

This genus is one of the most important and best represented groups of forest mosquitoes, and so many species have been collected that it is most convenient to discuss them under subgeneric headings.

Subgenus **Mucidus** Theobald

Not recorded from lowland dipterocarp forest.

Subgenus **Ochlerotatus** Lynch Arribalzaga

Not recorded from lowland dipterocarp forest.

Subgenus **Finlaya** Theobald

This is an important subgenus and 23 species have been collected in forest; in most cases breeding-places have been found and in all but one (*albocinctus*) the early stages have been collected or reared from eggs. For convenience the species may be discussed in the groups proposed by Knight and Marks (1952).

Group A (*kochi*-group)

In an earlier review (Macdonald, 1957) *avistylus* was noted as occurring in the Malay Archipelago, but there are in fact no records from Malaya itself. The only confirmed species of the group is *poicilius* which has been taken near, but not in, forest in Ulu Langat valley during a biting catch. This species is perhaps characteristic of wet and swampy areas. In addition to the records given previously (Macdonald, *l.c.*), several larval collections have been made in Pahang from the axils of *Pandanus* (screw-pines), growing in swamp forest, at heights up to 20 ft. (R. H. Wharton). This woody plant may be found in lowland dipterocarp forest, but not commonly.

In the IMR collection there is an additional species of the *kochi*-group, not previously recorded, which is related to *flavipennis* (Giles) and is almost certainly a plant axil breeder, perhaps with rather similar habits and distribution to *poicilius*.

Group B (*terrens*-group)

Three Malayan species of this group can be recognized, but their specific identities require confirmation. They are recorded as cf *assamensis*, cf *khazani* and cf *prominens*. All three occur in lowland forest, and each breeds in tree-holes or bamboo stumps and, rarely, split bamboo

(Table VIII). Several collections of cf *prominens* were made from a bamboo pot situated at a height of 32 ft. Occasional specimens of each species have been taken in biting catches.

Group D (*aureostriatus*-group)

Two subgroups are represented in Malaya and the more important is the *chrysolineatus*-subgroup. There are five species of this subgroup being provisionally recognized, but the relationships of two of them, species near *formosensis* and near *harveyi*, require closer study. The species near *harveyi* may prove to be in part *chrysolineatus*.

The breeding-places are summarized in Table VII, from which it is clear that the preferences of the species can not be very sharply defined. The first, *chrysolineatus*, has not been collected very often, but fallen bamboos may be the preferred habitat. The second, a species near *formosensis*, is rare, and has been collected only once at Ulu Gombak and once from Ulu Langat, but it has also been caught biting in some numbers near Kepong. The species near *harveyi* is common, and it is associated principally with bamboos, although a few collections have also been made from tree-holes. The apparent catholic preferences of this species (Table VII) may, however, be misleading, since the characters used to distinguish it from *chrysolineatus* are unsatisfactory and it is possible that the two species have been in part confused.

TABLE VII

THE COLLECTIONS OF THE *Aedes* (*Finlaya*) *aureostriatus* GROUP RECORDED FROM VARIOUS BREEDING-PLACES IN LOWLAND DIPTEROCARP FOREST, SELANGOR

Species	Total collections	Tree-holes	Bamboo pots	Bamboo stumps	Bamboos, fallen, split	Bamboos, with moderate holes	Bamboos, with small holes	Fallen leaves	Rock-pools	Temporary pools
<i>chrysolineatus</i> ...	9	1	2		4				1	1
species near <i>formosensis</i> ...	2			1	1					
species near <i>harveyi</i> ...	20	4	5	4	5	2				
<i>jugraensis</i> ...	31	2	1	4	14	1	1	7	1	
<i>saxicola</i> ...	16	2		1	1				12	
<i>aureostriatus</i>										
var. <i>greeni</i> ...	5	5								
var. <i>mikiranus</i> ...	1	1								

Ae. jugraensis is the most common species of the subgroup and nearly half of the collections have come from fallen, split bamboos. Occasional collections have also been made from bamboo stumps, tree-holes, etc., but the most important secondary source of larvae has been fallen leaves. These latter collections seem at variance with the others since the mosquito fauna of fallen leaves is generally composed of species which are not found commonly elsewhere, e.g. *Uranotaenia obscura* and *Zeugomyia gracilis*, but at present there is nothing else to suggest that two species are being confused.

The last species of the subgroup, *saxicola*, is clearly a rock-pool breeder. The adults reared from the two collections from a bamboo stump and a fallen bamboo require closer examination although superficially they agree with the description of *saxicola*.

All five species are found in lowland dipterocarp forest but, in addition, *chrysolineatus*, *saxicola* and the species near *harveyi* occur at higher altitudes in montane forest, e.g. at Fraser's Hill and at Cameron Highlands. Whereas the subgroup is well-represented in larval collections, it is significant that the adults are rarely attracted to man in biting catches. Probably each will feed on man but the preferred host is as yet undetermined.

There is one other Malayan species of group D: this is *aureostriatus*, belonging to the *aureostriatus*-subgroup. Almost all specimens belong to var. *greeni*, and a few agree with the description of var. *kanaranus*, including one female from a canopy catch, but the varietal

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differences are of doubtful significance. No larval differences corresponding with the minor adult differences have been observed between the two varieties. All six larval collections from lowland forest, together with two others from Jugra Hill near the coast, have come from tree-holes. Adults are uncommon in biting catches with human bait, but, as was mentioned, the species may bite in the canopy.

Group E (*mediovittatus*-group)

Only one Malayan species can be referred to this group, a species near *macfarlanei*. Larvae have been collected at Ulu Langat from a rock-pool (with *saxicola*), and from a concrete pit beside Ampang Reservoir at the forest fringe. No adults have been collected in biting catches. The larvae agree quite well with the brief description of *macfarlanei* larvae given by Barraud (1934: 181), and since this species has been recorded from Sumatra by Brug and from Cochin China by Borel, the Malayan material may well be *macfarlanei* s. str.

Group F (*alboannulatus*-group)

Two species of this group occur in forest, *albotaeniatus* and *alboincinctus* Barraud. The first is quite common, breeding in all of the habitats provided by bamboos and occasionally in tree-holes (Table VIII); adults may be taken in biting catches, usually in the early morning or late afternoon. The other species is rare; only a single female has been collected, and this was taken in a biting catch in the canopy at a height of 90 ft.

TABLE VIII

THE COLLECTIONS OF THE *Aedes* (*Finlaya*) *terrens* AND *alboannulatus* GROUPS RECORDED FROM VARIOUS BREEDING-PLACES IN LOWLAND DIPTEROCARP FOREST, SELANGOR

Species	Total collections	Tree-holes	Bamboo pots	Bamboo stumps	Bamboos, fallen, split	Bamboos, with large holes	Bamboos, with moderate holes	Bamboos, with small holes
<i>alboincinctus</i>	adult only						
<i>albotaeniatus</i> ...	26	4	3	5	7	1	5	1
cf <i>assamensis</i> ...	5	2		2	1			
cf <i>khazani</i> ...	1	1						
cf <i>prominens</i> ...	18	11	5	2				

Group H (*geniculatus*-group)

This group includes the *niveus*-subgroup, an interesting and important complex of forest species whose systematics have been revised by Knight and Stone (1946) and, more recently, by Colless (1958, 1959). In the lowland forest of Selangor 10 species have now been collected, including one which is probably new (Table IX). Several of these, together with a few other members of the subgroup, have also been found in non-forested areas, for instance by the coast.

The forest species fall into two groups: the larger includes *albolateralis*, *inermis* Colless, *litoreus* Colless, *pexus* Colless, *pseudoniveus*, *subniveus*, and *vanus* Colless, which breed principally in tree-holes, with occasional collections in bamboo stumps; the remaining group includes only *niveoides* and *novoniveus* both of which prefer bamboo stumps, fallen bamboos and bamboo internodes which have moderate or large-sized holes in the wall. In the absence of bamboos, *niveoides* certainly, and *novoniveus* possibly, will breed in tree-holes.

The undetermined species, *Aedes* species no. 9, is difficult to distinguish from *niveoides* in the adult stage, but there are clear larval and pupal differences. Although no larvae have been collected in the field, a small sibling series was obtained from a wild-caught female which was taken in a biting catch at Ulu Gombak.

TABLE IX

THE COLLECTIONS OF THE *Aedes* (*Finlaya*) *geniculatus* GROUP RECORDED FROM VARIOUS BREEDING-PLACES IN LOWLAND DIPTEROCARP FOREST, SELANGOR

Species	Total collections	Tree-holes	Bamboo pots	Bamboo stumps	Bamboos, fallen, split	Bamboos, with large holes	Bamboos, with moderate holes
<i>albolateralis</i> ...	32	25	6		I		
<i>inermis</i> ...	15	13		I	I		
<i>litoreus</i> ...	I	I					
<i>niveoides</i> ...	18		I	9	I	I	6
<i>novoniveus</i> ...	25		10	6	6		3
<i>pexus</i> ...	4	3		I			
<i>pseudoniveus</i> ...	10	6	3	I			
<i>subniveus</i> ...	3	3					
<i>vanus</i> ...	I	I					
species no. 9 ...	adults only						
<i>dissimilis</i> ...	13	9		4			

The main interest of the *niveus*-subgroup lies in the biting habits. Not only have most species been taken biting in the canopy but they are canopy dwellers by preference, and they form the major proportion of the canopy mosquito fauna. Unfortunately some species cannot be identified reliably with the female stage alone, e.g., *pseudoniveus* and *subniveus*, and when the mesonotal scaling is rubbed identification may not be possible. Consequently, the data derived from adult catches are not as accurate as might be desired.

The relative abundance of the individual species can be assessed from the collections recorded in Table IX, but *pseudoniveus* (including *subniveus*) is relatively more common in adult catches than in larval collections, and is often the most abundant species both on the ground and in the canopy. Although the canopy is the preferred adult habitat, most, if not all, species will readily bite at ground level. The available data are insufficient for final conclusions to be drawn about the biting-cycles, but, on the ground, adults will bite throughout the day, though never in large numbers. In the canopy there are indications of an increase in biting activity in the hour before sunset, and this high activity continues for one or two hours after sunset.

The single remaining species of group H is *dissimilis* (of the *dissimilis*-subgroup). Like most species of the *niveus*-subgroup, *dissimilis* breeds in tree-holes and bamboo stumps (Table IX); occasional adults are taken in ground-level biting catches during the day.

Subgenus **Christophersiomyia** Barraud

Only one species is known from Malaya, *gombakensis*, recently named and described by Mattingly (1959). This is an uncommon species and both larval collections that have been made came from tree-holes. The adults have rarely been taken in biting catches at Ulu Gombak.

Subgenus **Stegomyia** Theobald

This subgenus is one of the best represented in lowland forest, both in larval and in adult collections. There are many fewer species than in the subgenus *Finlaya*, but several are widely distributed both in forest and in non-forested areas. The recorded breeding-places in Selangor forest are shown in Table X.

Ae. albolineatus breeds principally in tree-holes but may also occur in one or other of the bamboo habitats. Although the larvae are quite common, adults have been taken only occasionally in daytime, ground catches.

Ae. albopictus is at times the most common mosquito in forest catches, appearing regularly throughout the year. Tree-holes are the principal natural breeding-places, but bamboo pots, including those at heights up to 50 ft., are readily utilized for breeding. Similarly, *albopictus*

will breed in a variety of natural bamboo breeding-sites, and, occasionally, in rock-pools. Biting is by day with peaks of activity in the early morning and late afternoon, but the peaks are not so pronounced in forest as in non-forested areas, where biting is minimal during the hot dry period at the middle of the day. Although *albopictus* bites predominantly near ground level, adults may be taken in canopy catches.

TABLE X

THE COLLECTIONS OF *Aedes* SUBGENUS *Stegomyia* RECORDED FROM VARIOUS BREEDING-PLACES IN LOWLAND DIPTEROCARP FOREST, SELANGOR

Species	Total collections	Tree-holes	Bamboo pots	Bamboo stumps	Bamboos, fallen, split	Bamboos, upright, cracked	Bamboos, with moderate holes	Bamboos, with small holes	Rock-pools
<i>albolineatus</i>	39	25	9	2	1		1	1	
<i>albopictus</i>	71	18	37	5	7		1	1	2
<i>desmotes</i>	adults only								
<i>mediopunctatus</i>	15		9		1	1	1	3	
<i>pseudalbopictus</i>	18		13	1	4				
<i>w-albus</i>	2	2							
species No. 10	1				1				
species No. 12	14		13	1					

So far only adults of *desmotes* have been collected in forest, and from those, sibling series have been reared in the laboratory. The adults are not common and they have all been taken at ground level by day. The thorax of the adult mosquito is strongly compressed laterally, suggesting that *desmotes* can penetrate narrow openings to reach the breeding-places (compare also *Armigeres* subgenus *Leicesteria* and *Udaya*).

Excluding for the moment the collections from artificial bamboo pots, *mediopunctatus* would appear to show a preference for relatively inaccessible breeding-places, such as bamboo internodes with small holes, and it is perhaps noteworthy that each of the collections from natural breeding-places came from bamboos which were dead or dying. The collections from bamboo pots are a little surprising in view of the absence of the species from bamboo stumps and tree-holes. Most collections were near ground level, but one was taken from a natural breeding-place at a height of 17 ft., and several of the pot collections were from 32 ft. Occasionally adults have been taken biting in the canopy, but probably the usual habitat is nearer ground level. During ground catches the peak biting activity is around midday and early afternoon (contrast *albopictus*), but in the canopy the peak is later, just before sunset.

Ae. pseudalbopictus is very similar in appearance to *albopictus*, but unlike *albopictus* no collections have yet been made from tree-holes. Rather strangely perhaps, fallen bamboos and bamboo pots provide the principal breeding records, and it seemed from the distribution of the collections that *pseudalbopictus* preferred the more highly situated bamboo pots at 32 and 52 ft. rather than those at ground level. The adults have a similar biting-cycle to that of *albopictus* and they occur commonly in ground catches.

Ae. w-albus has been collected in forest only twice as larvae, on both occasions from tree-holes. The adults are uncommon in biting catches.

A single male of the species recorded as *Aedes* species no. 10 was reared from a fallen bamboo collection. This specimen has since been sent to the British Museum (Nat. Hist.) with its associated skins.

Aedes species no. 12 has been collected more often. This species, which is probably undescribed, is very distinctive in appearance, with a narrow mesonotal stripe and patches of pleural scales which almost join to form stripes very like those of *scutellaris*. A series has been lodged in the British Museum (Nat. Hist.). As in the case of *pseudalbopictus*, collections have come mainly from bamboo pots, but with the exception of one collection from 32 ft. all were made near ground level. The single bamboo stump collection was from Ulu Langat, the remainder from Ulu Gombak. No adults have yet been taken in any biting catch.

Subgenus **Neomelaniconion** Newstead (= **Banksinella** Theobald)

There is little to be added to the earlier summary of the two Malayan species (Macdonald, 1957: 21). Occasional females of the species we record as *imprimens* (?= *auratus* Leicester) have been taken in biting catches at Ulu Gombak, but no larvae have been found as yet. The other species, *lineatopennis*, does not occur in forest.

Subgenus **Aedimorphus** Theobald

Four species have been collected at Ulu Gombak—*alboscuteatus*, *caecus*, *orbitae* and *vexans*. Of these, *alboscuteatus* and *vexans* have been collected from ground pools; *orbitae* has been taken a number of times from small temporary pools, such as form in cart-tracks and hoof-prints; while the larvae of *caecus* have not yet been collected in forest. Both *caecus* and *vexans* are more typical of open country than of forest and the specimens collected at Ulu Gombak probably represent secondary introductions from the forest fringe.

Adults of *alboscuteatus* and of *orbitae* are occasionally taken in daytime ground catches, but neither is a common species.

Subgenera **Skusea** Theo., **Rhinoskusea** Edw. and **Cancraedes** Edw.

Not recorded from lowland dipterocarp forest.

Subgenus **Aedes** Meigen

Little additional information can be added to the earlier review (Macdonald, 1957). Leicester and Edwards have described 8 species which are recorded from forest near Kuala Lumpur—*fragilis*, *incertus*, *indecorabilis*, *leicesteri*, *malayi*, *perditus*, *uncus* and *virilis*—but from our observations all of them are rare species. Only *incertus* and *leicesteri* have been identified with confidence from lowland forest, but *fragilis* has been collected from small patches of secondary forest in Kuala Lumpur. Four additional species have been collected from Ulu Gombak and Ulu Langat, and one of those agrees well with descriptions of *andamanensis*; the remaining three probably include previously described species, but confirmation is required.

Only one larval collection of *Aedes* has been made—from the Ulu Gombak aqueduct—and only three unidentified females were reared from this collection. All the remaining specimens were taken in adult catches or by sweep-netting.

The subgenus *Aedes* is perhaps better represented in coastal areas than in inland forest, and certainly in the former the group forms a more appreciable part of the biting population; in forest specimens are rarely taken in biting catches.

Subgenus **Paraedes** Edwards

This subgenus was recently reviewed systematically by Mattingly (1958), and most species are recorded from coastal areas rather than from inland forest. Leicester apparently collected *ostentatio* from forest at 4½ m. Pahang Road (Ulu Gombak), but there are no recent forest records. A single female of a new species has, however, been taken in a daytime biting catch at Ulu Gombak; this specimen has been deposited in the British Museum (Nat. Hist.), and was briefly mentioned by Mattingly (1958: 2).

Genus **Udaya** Thurman

Udaya was recently raised to generic status by Mattingly (1958: 4), and the only two species, *argyrurus* (Edw.) and *lucaris* Macdonald and Mattingly, both occur in the lowland forest of Malaya, though they might be described as rare. Breeding-places of only *argyrurus* have been found—in upright bamboo with cracks (once), fallen, split bamboos (twice), bamboo internodes with small holes (twice), and an internode with a moderate-sized hole (once).

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The adults of *argyrurus* are very strongly compressed laterally, particularly the thorax, and this is probably an adaptation to the preferred bamboo breeding-sites—which are reached through holes or narrow cracks in the bamboo wall (see also *Armigeres* subgenus *Leicesteria*, and *Aedes* (*S.*) *desmotes*). A few females have been taken in daytime biting catches.

Only two females of the remaining species, *lucaris*, have been collected, but a short sibling series was obtained from the eggs of one of them (see also Macdonald and Mattingly, 1960).

Genus *Heizmannia* Ludlow

Work on this genus has so far been less rewarding than might have been expected, for whereas adults are almost always represented in biting catches, and at times they form the major proportion of the catch, the breeding-places of most species cannot yet be satisfactorily defined. Barraud (1934: 300) states simply that the larvae may be found in tree-holes and bamboo stumps, but from the very considerable number of mosquito collections from these habitats in Malayan forest, *Heizmannia* larvae have been present only five times.

Nevertheless the genus is very well-represented in lowland dipterocarp forest, and all the known Malayan species occur, for instance, at Ulu Gombak, and probably also at Ulu Langat. In addition, some species, e.g. *H. scintillans*, may be collected in swamp forest, and even in fairly open country.

Although the genus has been recently revised by Mattingly (1957b), as a result of which most Malayan species can be readily identified, there remains a proportion of each adult catch which can not be named with confidence. This applies particularly to the *scintillans*—*indica*—*metallica* group, which is often common in catches. In the previous review of Malayan non-anophelines (Macdonald, 1957), three species were not named. The following names can now be substituted: n.sp. near *communis*=*macdonaldi*; n. sp. near complex=*stonei*; n. sp. (= *H. indica* auct.)=*reidi*; each was described and named by Mattingly(1957b).

The recorded breeding-places are shown in Table XI, from which it may be seen that the larvae of five species have not yet been collected; however, the early stages of two of these, *achaetae* and *reidi*, have been obtained by laboratory rearings from egg-batches. Of the five species whose larvae have been collected, *aureochaeta*, *communis*, *macdonaldi* and *scintillans* appear to have a preference for breeding in bamboo internodes with small or moderate-sized holes; in the case of *macdonaldi* there is a preference for young dead or dying bamboos. The remaining species, *stonei*, has been collected only twice, on both occasions from a tree-hole. But the number of larval collections does not indicate the true abundance of these mosquitoes; and the individual figures may be misleading, for the species *macdonaldi*, although apparently the best-represented as larvae, is in fact much less common in adult catches than *scintillans* or *aureochaeta*.

TABLE XI

THE COLLECTIONS OF *Heizmannia* RECORDED FROM VARIOUS BREEDING-PLACES IN LOWLAND DIPTEROCARP FOREST, SELANGOR

Species	Total collections	Tree-holes	Bamboos, fallen, split	Bamboos, with moderate holes	Bamboos, with small holes
<i>achaetae</i>	adults only				
<i>aureochaeta</i>	2			2	
<i>communis</i>	4		1		3
<i>indica</i>	adults only				
<i>macdonaldi</i>	8		1	4	3
<i>metallica</i>	adults only				
<i>reidi</i>	adults only				
<i>scintillans</i>	5	1		3	1
<i>stonei</i>	2	2			
species no. 1	adults only				

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Since the adults are quite common at certain times of the year, the biting-cycles of the species can be better defined than the breeding-places. The general pattern seems to be rather similar in each case: periods of low activity in the early morning and late afternoon, but high activity during late morning and early afternoon. No biting has been recorded during the night, nor elsewhere than at ground level. This pattern of biting behaviour is rather unusual in that the activity peak is reached at the hottest time of the day; most other mosquitoes show a depression in their biting curves at that time, although there are some exceptions e.g. *Armigeres moultoni*.

Because larvae were difficult to find in the field, a number of sibling series have been reared from egg-batches laid by wild-caught females. Unfortunately, the mortality rate among adult *Heizmannia* mosquitoes brought into the laboratory is high, particularly if the mosquitoes are unfed; and even fully-fed adults often die within a day or two of their capture. Since all species of *Heizmannia* have been found to be very reluctant to feed in the laboratory, the adults are best allowed to feed in the field when they come to attack human bait. Since no observations have been recorded previously on the eggs or egg-laying, a few words may be added on this subject.

The eggs are readily laid on damp filter paper, and they are laid scattered individually, not as a raft. Oviposition occurs 3-4 days after the blood-meal, but delays of up to 9 days have been recorded. After being laid the eggs are best kept on moist filter paper for several days and allowed to dry slowly before being immersed in water. On immersion it is unusual for the larvae to hatch immediately, and quite commonly they will not hatch until nearly a week later. The hatching behaviour of the eggs may vary from one specimen to another of the same species, and sometimes among eggs of the same batch. In one case a batch of some 46 eggs was laid by a female *stonei* four days after feeding; half of the eggs were immersed in water 4 days later, but hatching only began after a further 12 days (14 adults were reared); the remaining eggs were kept dry for 3 weeks and then immersed, but there was no hatching until 17 days later when the first of seven larvae hatched over a period of 3-4 days.

A number of egg batches of *scintillans* have been maintained. In six cases the eggs were retained for a period of 3 days to mature; on immersion in water, hatching commenced on a different day in each case—after 2, 3, 6, 7, 9 and 10 days respectively. The most effective period for maturation of the eggs may be 6-7 days.

In the laboratory the larval life may be quite lengthy, often 2-3 weeks or more; the pupal stage usually lasts three days, occasionally four.

Very marked fluctuations in the numbers of *Heizmannia* have been recorded throughout nearly two years' observations. There seems to be some correlation between the peaks and periods of high rainfall, and this would suggest breeding-places which are open, such as tree-holes and bamboo stumps, but there are still a number of puzzling features to be resolved before a clear statement will be possible. The fluctuations in numbers bear no similarity to those of *Armigeres* subgenus *Leicesteria* (see Macdonald, 1960b, this *Study*), nor do they coincide with those of the known open-container breeders, such as *Aedes*. They will therefore probably not be fully understood until the breeding-places can be clearly defined.

Genus *Armigeres* Theobald

This genus is well-represented in the forest, particularly the subgenus *Leicesteria*. However, since a full account of the systematics and ecology of *Leicesteria* is given elsewhere (Macdonald, 1960b, this *Study*), only the subgenus *Armigeres* need be discussed in detail here.

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Subgenus *Armigeres* Theobald

Although 11 species have been collected in forest, none is very common either in adult or in larval collections; some species are certainly rare, others are taken periodically in small numbers. The larval collections that have been made are shown in Table XII, from which it is clear that there are still many gaps to be filled. The habits of most species can not therefore be satisfactorily defined, but a few tentative conclusions may be drawn.

Barraud (1934: 320) gives the breeding-places of *aureolineatus* as "coconut-shells, etc." but Leicester's single collection and ours came from the shell of an unidentified jungle fruit. The larvae have never been collected from coconut-shells in Malaya. This is a rare species in Malaya recorded only from Ampang forest and Ulu Gombak.

The collections of *confusus* (Table XII) suggest that it may select bamboo stumps; the collections from bamboo pots included a few from 20 ft. and 32 ft. As many as 100 eggs may be laid by a single female after a blood-meal.

TABLE XII

THE COLLECTIONS OF *Armigeres* SUBGENUS *Armigeres* RECORDED FROM VARIOUS BREEDING-PLACES IN LOWLAND DIPTEROCARP FOREST, SELANGOR

Species	Total collections	Tree-holes	Bamboo pots	Bamboo stumps	Bamboos, fallen, split	Ginger flower bracts	Shell of a jungle fruit	Rock-pool
<i>aureolineatus</i>	1						1	
<i>confusus</i>	8		5	2				1
<i>conjungens</i>	4					4		
' <i>durhami</i> '	2		2					
<i>jugraensis</i>	3	2			1			
<i>maiae</i>	2	2						
<i>maximus</i>	adults only							
<i>moultoni</i>	adults only							
<i>subalbatus</i>	1							1
species no. 1	2			1	1			
species no. 3	adults only							

One of the few species with well-defined habits is *conjungens*. Larvae may quite often be found breeding in the water which collects in the bracts of the inflorescence of the wild ginger plant *Zingiber spectabile*; *Topomyia tenuis* is often associated with it. Close observations on *Z. spectabile* have not yet been made, but the impression gained is that this plant flowers principally at the beginning of the main rains in August or September; and there is a corresponding rise in the numbers of *Ar. conjungens*.

Both *jugraensis* and *maiae* may be primarily tree-hole breeders, but additional collections are required to confirm this. The females of these two species are very alike and no convenient character for their separation has yet been found. An area of white scales on the halteres may perhaps serve to distinguish *maiae*.

Ar. maximus is an inadequately described species which has been taken on a few occasions in catches at the forest fringe of Ulu Langat and Sungei Buloh. The females do not readily feed on man, and, in the laboratory, prefer guinea-pig. The early stages are unknown.

The status of the species shown as *subalbatus* (= *obturbans*) and '*durhami*' is uncertain. No males have been collected from forest yet, and the material available requires more critical study than has so far been possible. Thurman (1958) and Stone and Thurman (1958) have to some extent clarified the identity of the species in what might be called the *subalbatus*-complex,

but the identification of some Malayan specimens, particularly females, still presents problems. *Ar. subalbatus* is more typical of urban areas, breeding at times in septic tank systems, and of coastal areas, often breeding in fallen, damaged coconuts (see Macdonald, 1960a), but since it is probably a forest-dweller primarily, the identification of our specimens may well be correct. Two other species which are found in forest but have become successfully adapted in suburban and coastal areas respectively are *confusus* and *moultoni*.

The position regarding '*durhami*' is more uncertain. At present we prefer to confine the name to those specimens which we have collected in montane forest fringe, as at Fraser's Hill; these specimens fit Edwards' original description more exactly than do those from lowland areas, and the type locality is Bukit Kutu, Selangor, situated near Fraser's Hill.

The two unnamed species are quite distinct. The first, species no. 1, is probably the same as that described by Borel from Indochina (1930: 178) as "*Armigeres* sp. ?" since the terminalia agree with his figure. The second, species no. 3, is very similar to *moultoni*, but the white scaling on the hind femur is more extensive and the male terminalia are distinct; a sibling series was reared from an egg-batch.

All those species which have been collected in biting catches have been taken by day, and although the numbers have generally been small, it seems that most species, with the exception of *moultoni*, feed during the late afternoon. In the case of *moultoni*, although the larvae have not been collected, good numbers have been taken at times in adult catches, from which it appears that the highest biting activity is reached during the early afternoon. It may be noted, however, that in the less shaded conditions of the *Nipa*-palm plantations of the coast, *moultoni* shows indications of two peaks of activity, one about two hours after sunrise and another two or three hours before sunset. In other words there is less activity during the hot part of the day, as one might expect. Undoubtedly the degree of shade is an important factor influencing biting times. Similarly, outside the forest, *subalbatus* has two peaks of activity; the main peak falls in the half-hour before and the half-hour after sunset, with another in the equivalent period at sunrise. Although principally a day-biter, *subalbatus* has also been collected during the night in non-forested areas.

In all the species that have been observed in the laboratory, and that includes most Malayan species, egg-laying usually takes place 3-4 days after a blood-meal and the eggs are laid singly as in the case of many species of *Aedes* and *Heizmannia*. In those species which have been investigated, the eggs can be slowly dried and stored for a period, after which they will hatch on immersion in water. This feature has obviously a survival value in nature.

Most species are easily kept alive under laboratory conditions, and will feed fairly readily on man or guinea-pig.

Subgenus **Leicesteria** Theobald

The distribution of this subgenus is closely related to the distribution of forest bamboos, and the ecology of the species, so far as it is known, is discussed in the following paper of this *Study* (Macdonald, 1960b). Here it is only necessary to record that 13 species have been collected in lowland dipterocarp forest, and that these form an important and common constituent of the mosquito population. Several species have the thorax strongly compressed laterally, an adaptation to entering bamboo internodes through very small holes in the bamboo culm.

Genus **Culex** Linnaeus

As in the case of the genus *Aedes*, the subgenera of *Culex* are best considered separately. While the genus as a whole is not a forest group, there are a number of species which may

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occur there in moderate numbers. A few of these might be correctly described as forest species, but most are more typical of scrub vegetation and have probably become secondarily adapted to the conditions in the forest fringe and in secondary forest.

Most species bite at night, but in the shade of the forest it is not uncommon to find adults biting by day, especially in the morning. Generally the eggs are laid as a raft, but there are many species on which observations have not yet been made, and it is possible, though unlikely, that eggs are laid individually in some cases.

Subgenus **Lutzia** Theobald

Only one of the two Malayan species has been collected in lowland forest, *halifaxi*. This species is rather uncommon, and larvae have been collected on only a few occasions—once from a forest pool, once from a tree-hole, and once from a cavity in a fallen, rotting tree-trunk. The adults have been collected only rarely.

Subgenus **Acalleoemyia** Leicester

Not recorded from forest. Nothing could be said about the distribution or habits of the single species, *obscurus*, a few years ago (Macdonald, 1957), but a number of collections have since been made in coastal areas. Larvae are found principally in the axils and stumps of *Nipa*-palms.

Subgenus **Mochthogenes** Edwards

A single species has been collected a number of times from the still water in the small aqueduct at Ulu Gombak. This species is certainly not *malayi*, but no comparison has been possible with the other recorded Malayan species, *hackeri*. The male terminalia resemble those of the Indian species *castrensis*, though the Malayan specimens are probably specifically distinct.

Subgenus **Neoculex** Dyar

The single Malayan species, *brevipalpis*, is common in lowland forest; it is, in fact, probably the most common species of *Culex* in larval collections, and may also be taken in biting catches. The principal breeding-places are tree-holes (36 of 59 collections), but larvae may also be found in fallen split bamboo (8/59), bamboo stumps (5/59), bamboo pots (7/59), and in bamboo internodes with moderate holes (2/59) or with small holes (1/59).

This species is not by any means limited to forest, but may occur in suburban areas and also in coastal districts.

Subgenus **Lophoceraomyia** Theobald

The subgenus *Lophoceraomyia* is well-represented in forest, but there have been many difficulties in identifying the various species. More than 100 larval collections have been made, and from many of these, reared adults, each with its associated larval and pupal skin, have been preserved for future study. The bulk of this large collection is now being studied by Dr D. H. Colless, and only when the systematics have been clarified will it be possible to discuss the ecology of the individual species.

For the time being all that can be said is that eight species, several probably new, have been recognized by Dr Colless from the forest collections. These include *cinctellus*, *mammilifer*, *minor*, *quadripalpis*, and *rubithoracis*. The main sources of larvae have been tree-holes (28 of 109 collections), bamboo stumps (26/109), and fallen, split bamboos (28/109). In addition, collections have been made from pools—from the edges of marsh, pools beside streams, etc.—and occasional collections have been made from rock pools and, once, from a fallen leaf on the forest floor.

A few adults are not uncommon in biting catches, usually after sunset but occasionally during the day in shade. During the day catches *cinctellus* occurs in small numbers, and this same species has also been collected biting in the canopy.

Subgenus **Culiciomyia** Theobald

There are only three species of this subgenus so far recorded from lowland forest, but like many others of the genus *Culex* they probably only occur in secondary forest, which they may have entered from nearby scrub vegetation. The first, a species near *bahri*, has been collected only twice—from a small temporary pool in a timber-lorry track, and from a fallen, split bamboo. The second species is probably that described by Leicester (1908: 158) as *graminis*, which is a doubtful synonym of *fragilis*. (This latter species, *fragilis*, is typically found in coastal areas in Malaya, but this would not necessarily preclude its occurrence in forest.) Larvae have been collected from jungle pools on two occasions. The third species, *nigropunctatus*, has been collected from swamp pools at Ulu Gombak, but is more typical of non-forested areas. It is almost certainly a secondary introduction into the forest fringe, where small populations may be maintained. None of the three species in common.

Subgenus **Culex** Linnaeus

Once again a number of species may occur casually in secondary forest, and it is very doubtful whether any has become established in primary forest. Only *mimulus* and *pseudovishnui* have been collected both as larvae and as adults in the areas under discussion, and in each case the larvae came from ground pools. Small numbers of *pseudovishnui* have been taken quite regularly in biting catches, often in day catches and occasionally in the canopy.

In addition, the following species have occurred occasionally in biting catches:—“*bitaeniorhynchus*” (there are probably several Malayan species being confused under this name), *fuscocephalus*, and *gelidus*.

Genus **Anopheles** Meigen

Although most of our collecting in forest has been directed towards culicine and megarhinine mosquitoes, both the larvae and the adults of a number of anophelines have also been collected. The systematics and ecology of most Malayan species are now relatively well-known and recorded, but for the sake of completeness a brief account of the forest species may be included here.

More complete data are provided by Gater (1934, 1935), Reid (1949), Reid and Hodgkin (1950), and Colless (1956, 1957).

Subgenus **Anopheles** Meigen

Ten species of this subgenus have been collected and most are pool-breeders. One of the most common is *aitkeni*, which has been collected from small pools of clean water beside the River Gombak as well as from the Ulu Gombak aqueduct. The adults are not uncommon in biting catches, and may be taken by day in shade.

An. montanus has been collected from rather similar larval breeding-sites to those of *aitkeni*: from ground pools, the aqueduct, and from side pockets of the river. Also from the aqueduct in the past (1933-1935), but not recently, has come *barbumbrosus*, while recently two undescribed species near *barbirostris* have been found there; and one of the latter has also been taken from swampy land at 11 m. Ulu Gombak Road and from a ground pool at the 17th mile.

An. annandalei and *asiaticus* have quite different breeding habits from the others: several collections of the former have been made from tree-holes, while *asiaticus* has been taken mainly from fallen, split bamboo.

The three remaining species of the subgenus, *roperi*, *umbrosus*, and a species near *letifer*, have been collected occasionally in adult catches on human bait, or as larvae from the aqueduct.

Subgenus **Myzomyia** Blanchard

Most of the seven species collected, as was the case in the preceding subgenus, are ground-pool breeders. *An. l. leucosphyrus* seems to prefer muddy pools, such as the small pools of water that collect in wheel tracks, and *balabacensis introlatus* occurs in the aqueduct, whereas *riparis macarthuri* breeds in cleaner, seepage pools and the side pools of streams; larvae of *kochi* may be found at the forest fringe in open, muddy pools, and *maculatus* breeds in pools of seepage water. Both the remaining two species, *hackeri* and *watsoni*, breed in fallen, split bamboos, but neither is very common.

None of these species of *Anopheles* has been taken very regularly in our adult catches, principally because, as was explained earlier, the catches have been mostly made by day. It is of interest to note, however, that *An. l. leucosphyrus* and the closely related *balabacensis introlatus* were taken in larger numbers in the canopy than at ground level.

SUMMARY

1. During the past 3-4 years investigations have been made into the ecology of the mosquitoes of the lowland dipterocarp forest of Selangor, Malaya. In this account of the work, a short summary of the main features of the forest is given, and the areas where mosquitoes were collected are defined; most collecting has centred around Ulu Gombak Forest Reserve, an area of disturbed or secondary forest.

2. In the course of the investigations more than 500 larval collections were made, each larva being reared to the adult stage, and regular adult catches have continued for more than two years. The breeding-places in the forest are defined and shown in tabular form together with the number of species that has been collected from each.

3. The mosquitoes are then discussed by genera, and in most groups the collections of each species from each type of breeding-place are summarized in tabular form. The preferred breeding-places, the biting habits, the egg-laying habits, etc., are discussed in the text in each case where data are available.

4. Altogether 163 species have been collected either as larvae or as adults, and in each case series were preserved for future systematic study. At least 25, and perhaps more than 30, of those species are new and undescribed, or have been described recently in part or entirely from Selangor forest specimens; the early stages of many more species were collected for the first time. There are, in addition, about 11 other species recorded from Malayan forest which were not collected in these investigations.

ACKNOWLEDGEMENTS

It is fitting that we record first our indebtedness to the assistants and mosquito collectors of the Division of Entomology of this Institute, each of whom has contributed assistance in the field and in the laboratory; in particular, Mr S. Mahadevan, who has been principal assistant to one of us for several years, and Mr A. Ganapathipillai, senior assistant in the Division, deserve special mention. In addition, several of the field staff of the United States Army Medical Research Unit contributed towards the adult and larval mosquito collecting. Thanks are due to Che Mohamed bin Omar, who drew the map, and we are grateful also to Mr J. Wyatt-Smith of the Forest Research Institute for advice on several botanical questions, to Mr R. N. Hilton of the Rubber Research Institute for the identification of *Polystictus xanthopus*, and to Dr J. A. Reid of this Institute who was ready at all times to discuss problems and to offer helpful suggestions.

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